US005790574A

United States Patent [19]

Rieger et al.

[11] Patent Number: 5,790,574

[45] Date of Patent: *Aug. 4, 1998

[54] **LOW COST, HIGH AVERAGE POWER, HIGH BRIGHTNESS SOLID STATE LASER**

[75] Inventors: **Harry Rieger**; **Henry Shields**, both of San Diego; **Richard M. Foster**, Manhattan Beach, all of Calif.

[73] Assignee: **IMAR Technology Company**, San Diego, Calif.

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,934,875.

[21] Appl. No.: **845,185**

[22] Filed: **Apr. 21, 1997**

Related U.S. Application Data

[63] Continuation of Ser. No. 503,373, Jul. 17, 1995, abandoned, which is a continuation-in-part of Ser. No. 295,283, Aug. 24, 1994, Pat. No. 5,434,875, Ser. No. 339,755, Nov. 15, 1994, Pat. No. 5,491,707, and Ser. No. 429,589, Apr. 27, 1995, abandoned.

[51] **Int. Cl.**^{6} **H01S 3/10**

[52] **U.S. Cl.** **372/25**; 372/18; 372/12; 372/13; 372/22; 372/30; 372/31; 372/70

[58] **Field of Search** 372/25, 18, 12, 372/13, 22, 31, 30, 70, 75, 69

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,434,875 7/1995 Rieger et al. 372/25

Primary Examiner—Leon Scott, Jr.
Attorney, Agent, or Firm—John R. Ross

[57] **ABSTRACT**

A high average power, high brightness solid state laser system. We first produce a seed laser beam with a short pulse duration. A laser amplifier amplifies the seed beam to produce an amplified pulse laser beam which is tightly focused to produce pulses with brightness levels in excess of 10^{11} Watts/cm^2. Preferred embodiments produce an amplified pulse laser beam having an average power in the range of 1 kW, an average pulse frequency of 12,000 pulses per second with pulses having brightness levels in excess of 10^{14} Watts/cm^2 at a 20 μm diameter spot which may be steered rapidly to simulate a larger spot size. Alternately, a kHz system with several (for example, seven) beams (from amplifiers arranged in parallel) can each be focused to 20 μm and clustered to create effective spot sizes of 100 to 200 μm. These beams are useful in producing X-ray sources for lithography.

34 Claims, 10 Drawing Sheets